

# Integrated design and control of wind turbines

**Barahona Garzon, Braulio**

*Publication date:*
2010

*Document Version*
Publisher's PDF, also known as Version of record

# Integrated design and control of wind turbines

Braulio Barahona
Ph.D. student, Wind Energy Systems

Wind Energy Systems Workshop on
Wind power plant control and flexible load management
November 2nd, 2010

Risø DTU
National Laboratory for Sustainable Energy

# Acknowledgments


- Wind Energy Systems
  - Poul Sørensen (main supervisor)
  - Nicolaos Cutululis
  - Anca Hansen
- Aeroelastic Design
  - Peter Bjørn Andersen
  - Lars Christian Henriksen
  - Helen Markou

# Outline

1. Introduction
   - Motivation
   - Objective
   - State-of-the-art
2. Frequency support
   - Model description
   - Simulation results
3. Summary

# Introduction

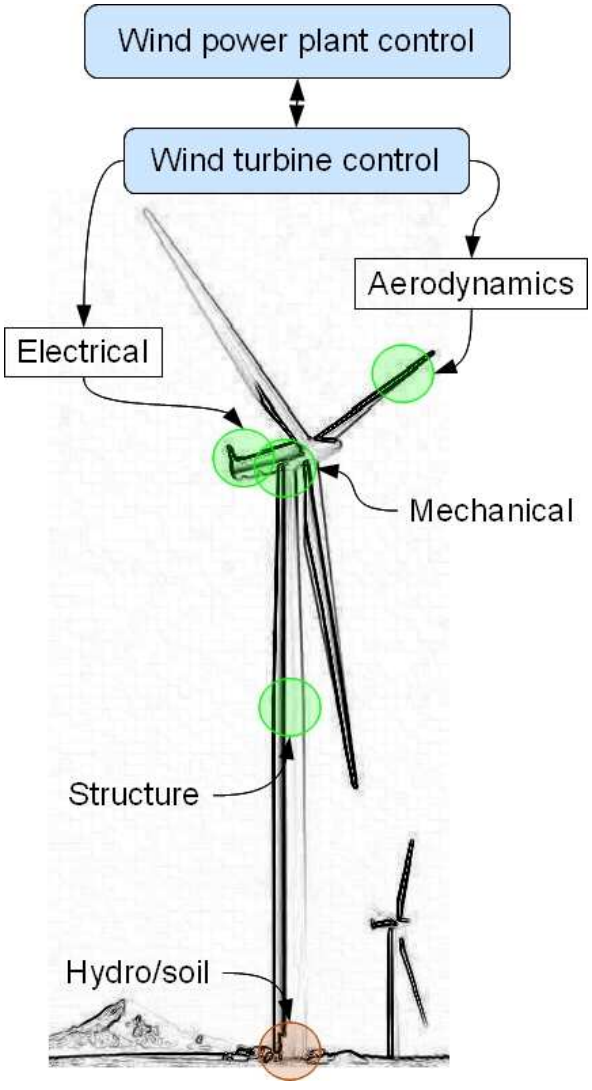


Illustration of wind turbine subsystems

## Motivation

Wind turbines under **operating conditions** such as:

- frequency control,
- voltage dips, or
- storm fronts

may observe significant loads.

In this context, the **dynamic interactions** amongst the different subsystems of a wind turbine may prove to be relevant. The focus of this work is on

- aerodynamic,
- structural,
- mechanical,
- electrical and
- control

subsystems of wind turbines.

# Introduction

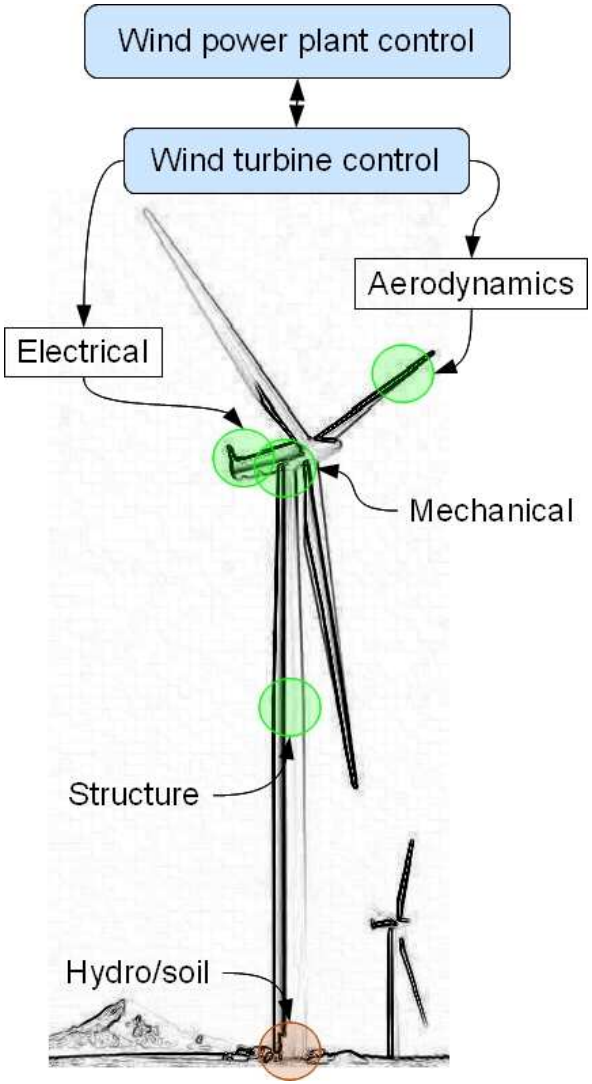


Illustration of wind turbine subsystems

## Motivation

Wind turbines under **operating conditions** such as:

- frequency control,
- voltage dips, or
- storm fronts

may observe significant loads.

In this context, the **dynamic interactions** amongst the different subsystems of a wind turbine may prove to be relevant. The focus of this work is on

- aerodynamic,
- structural,
- mechanical,
- electrical and
- control

subsystems of wind turbines.

# Introduction

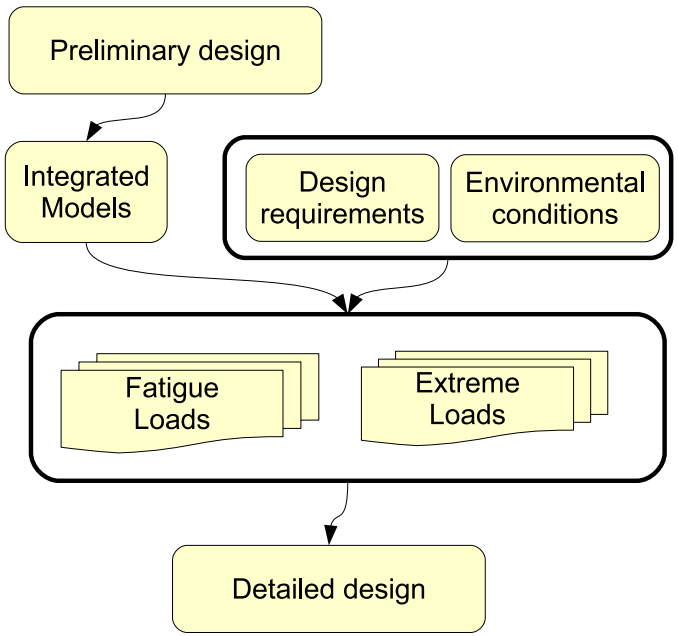


Figure: Basic description of wind turbine design process

## Objective

The **general objective** is to develop a framework for the analysis of wind turbines taking into consideration operating conditions relevant for the safe operation of the power system.

Three **milestones** of the project are:

1. Implement a simulation platform (HAWC2, Matlab/Simulink).
2. Define study cases (models and control).
3. Estimate impact on wind turbine loads.

# Introduction

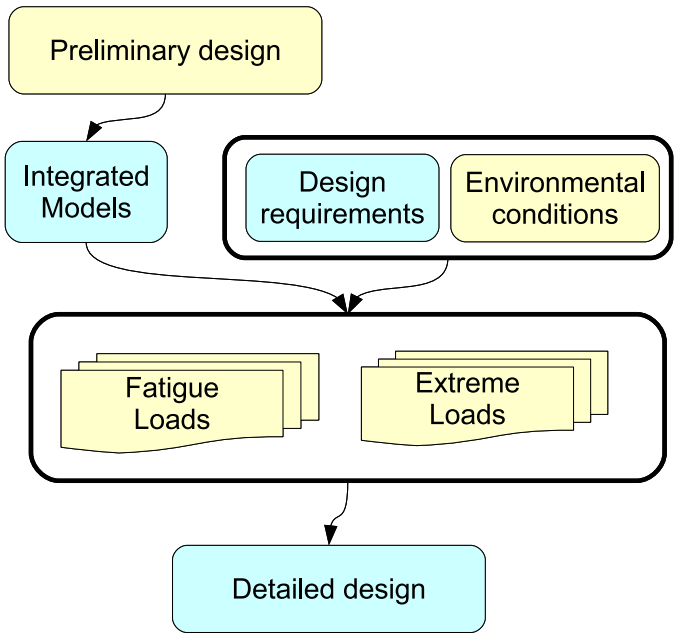


Figure: Basic description of wind turbine design process

## Objective

The **general objective** is to develop a framework for the analysis of wind turbines taking into consideration operating conditions relevant for the safe operation of the power system.

Three **milestones** of the project are:

1. Implement a simulation platform (HAWC2, Matlab/Simulink).
2. Define study cases (models and control).
3. Estimate impact on wind turbine loads.

# State-of-the-art

Software used for wind turbine simulation:

- Multi-domain modeling
  - MapleSim (Maple)
  - Modellica (Open source)
- Modal software
  - FAST (NREL)
  - Flex5 (DTU)
  - Bladed (Garrad Hassan)
- MBD/FEM software
  - S4WT (SAMTECH)
  - SimPack
  - **HAWC2** (Risø)

*... this list is not exhaustive.*

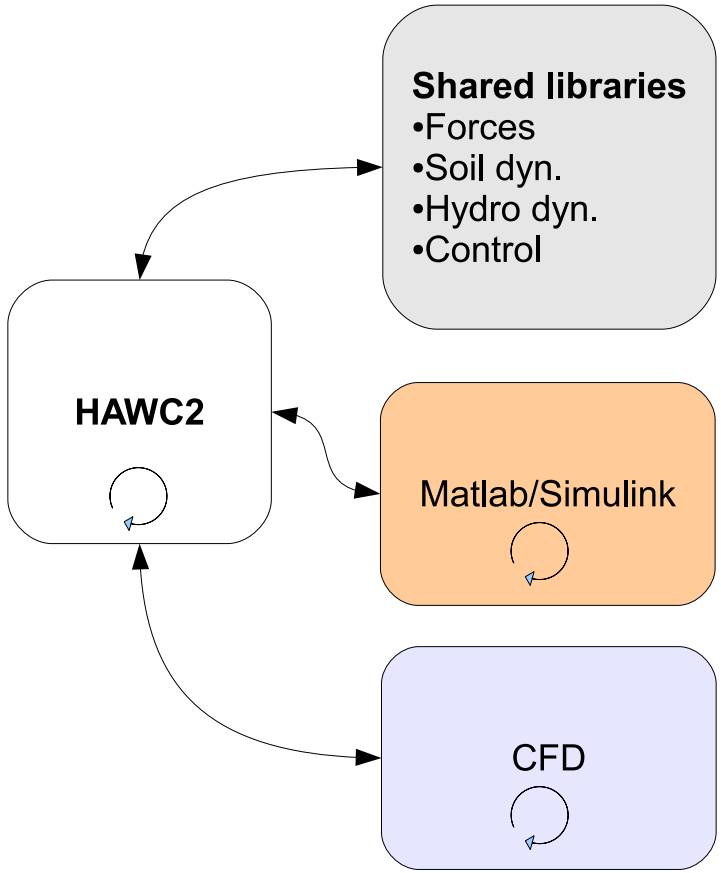


Figure: HAWC2 external interfaces

# HAWC2 - Matlab link

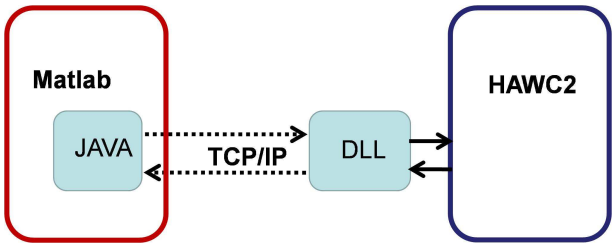


Figure: Description of HAWC2-Matlab link

- Keep both applications stand-alone.
- Make use of built-in interfacing capabilities in Matlab.
- Applications run simultaneously and interact every time step.

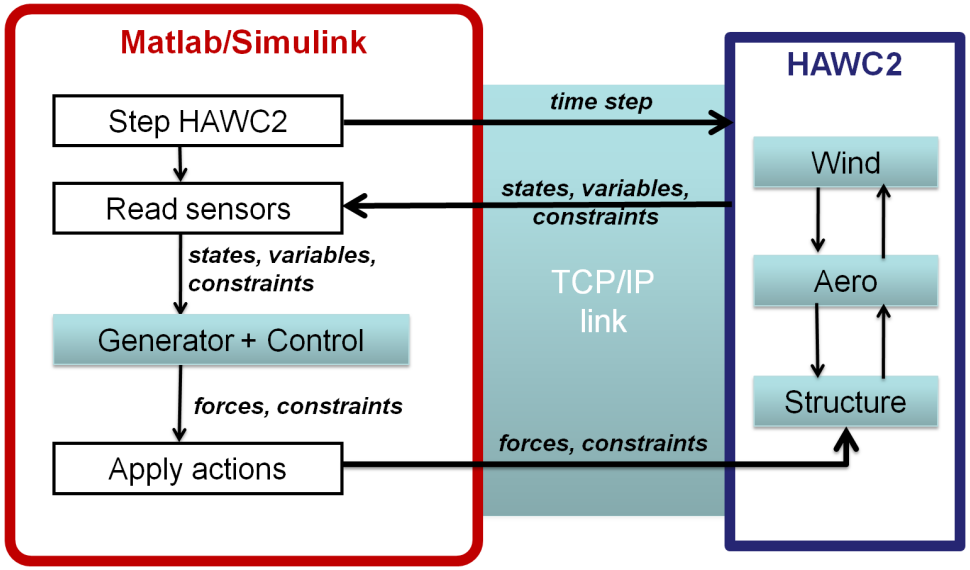


Figure: Integrated Simulation Flow chart

# Model description

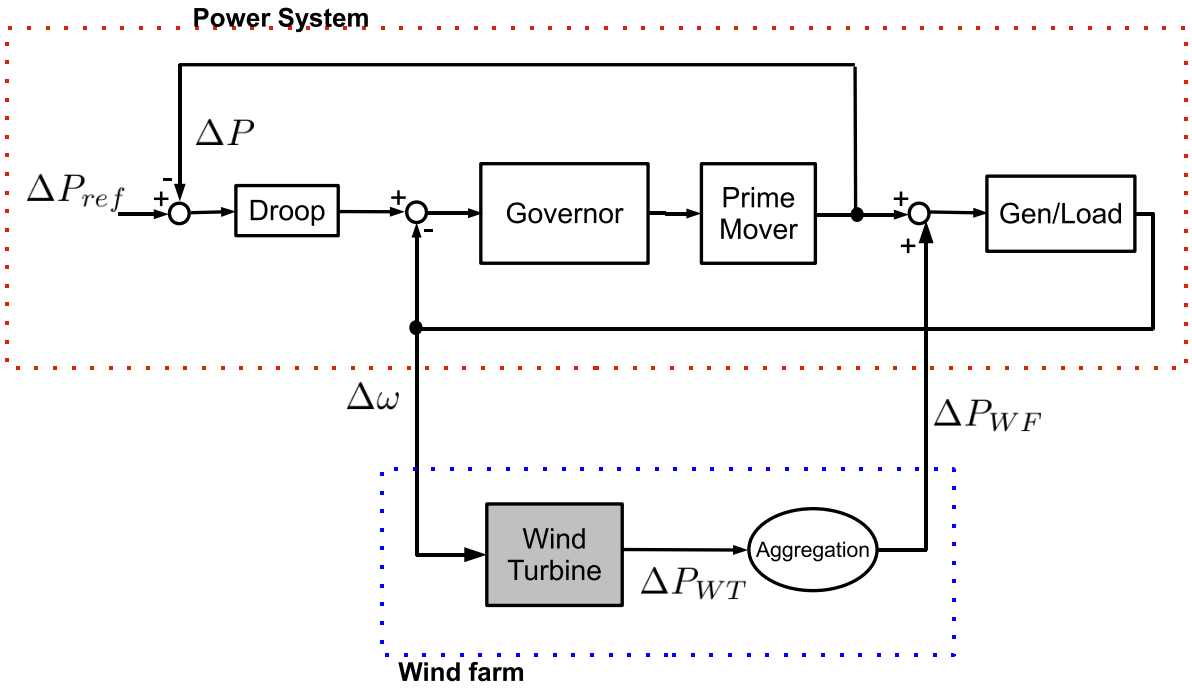


Figure: Description of power system model

# Frequency support

Wind turbine inertia emulation at rated wind speed.

Simulation of wind turbine inertia emulation in case of loss of load

- Total capacity of the power system is 60 MW.
- A 12 MW wind farm (DFIG wind turbines) is
  1. producing rated power (12 m/s), or
  2. disconected (no WT)
- Inertia Emulation control law
  $\Delta P = 2H_{wt}\omega\frac{d\omega}{dt}$
- A 8% loss of generation is simulated.

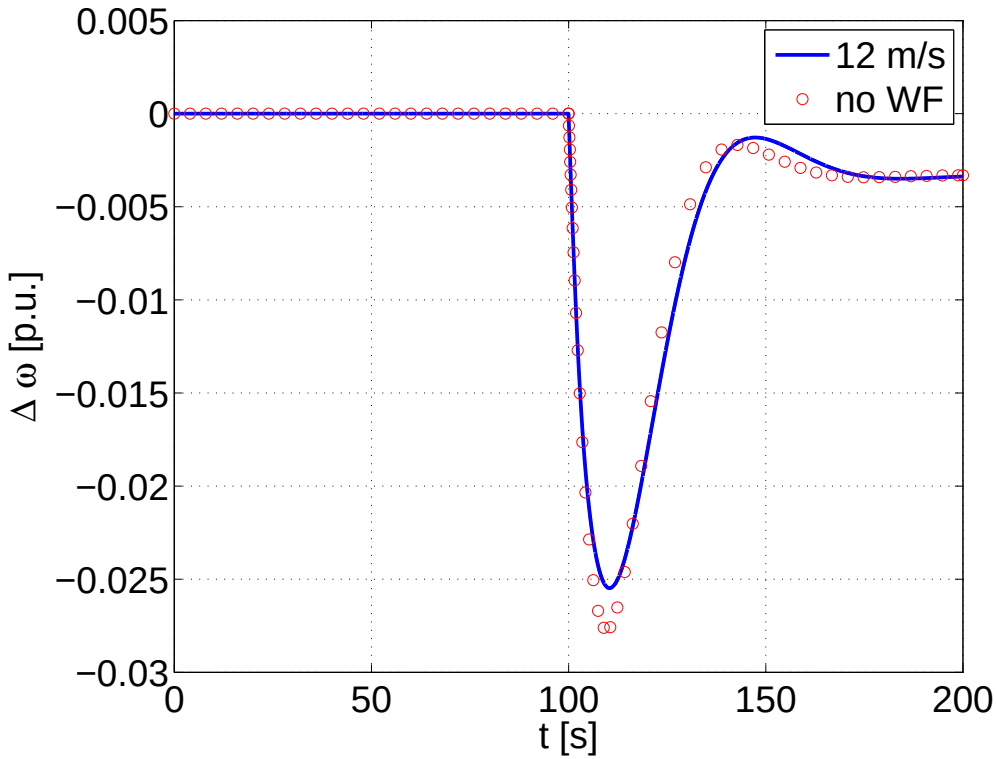


Figure: Power system response to loss of generation

# Frequency support

Wind turbine inertia emulation at rated wind speed.

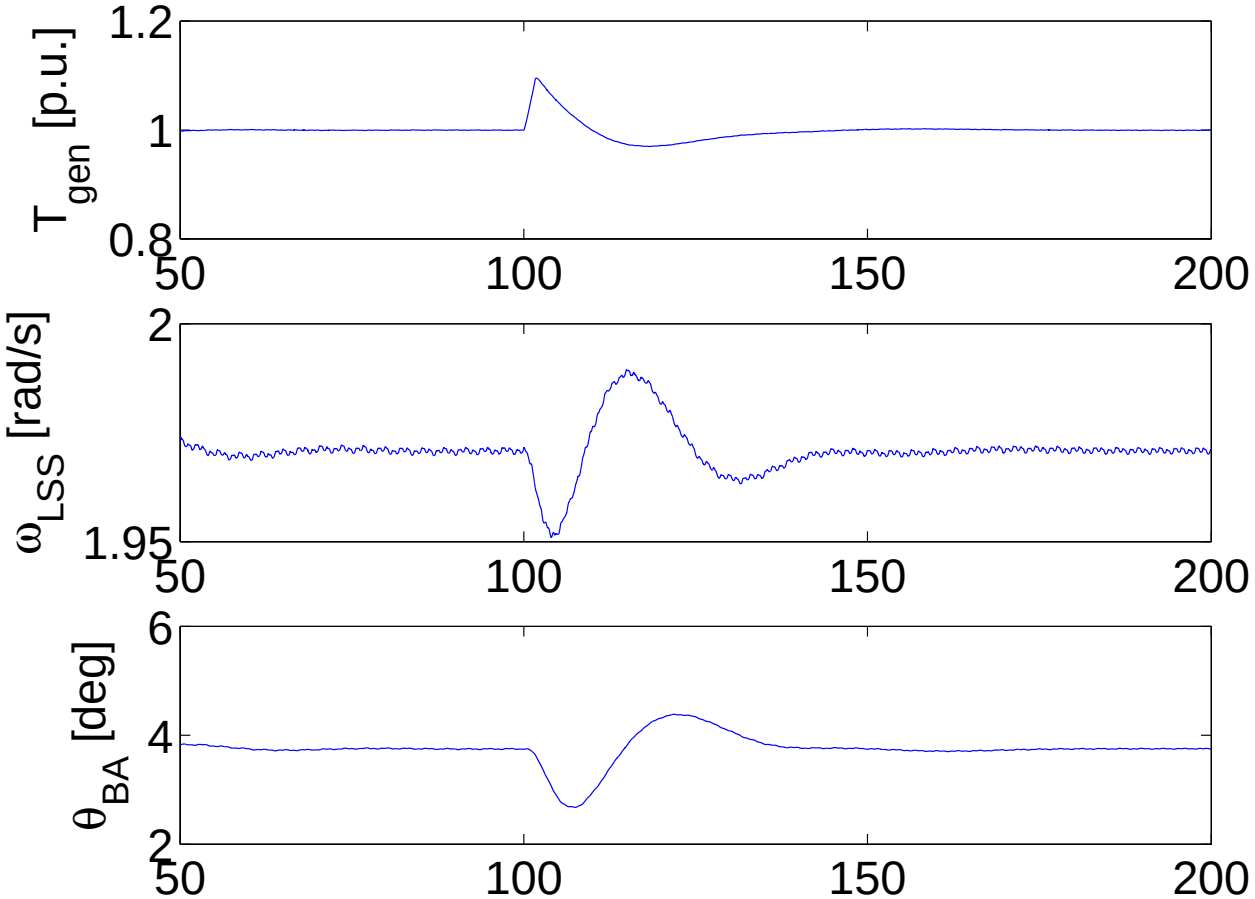


Figure: Wind turbine inertia emulation. From top to bottom: Generator Torque, Low-speed Shaft speed, and Blade angle

# Frequency support

Wind turbine inertia emulation at rated wind speed.

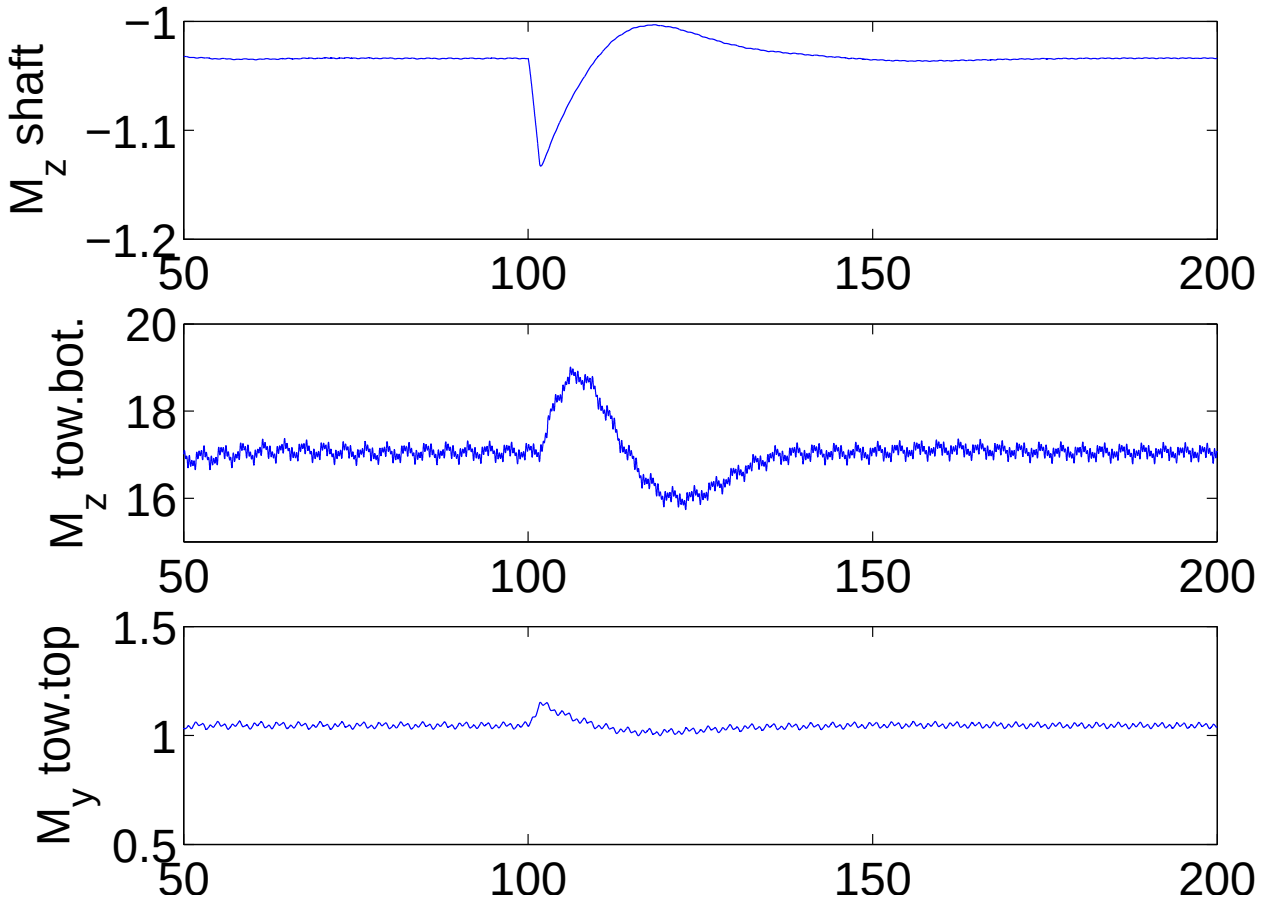


Figure: Wind turbine loads while emulating inertia. From top to bottom: Low-speed shaft moment, Tilting moment at tower bottom, and Yaw moment at tower top (all in MNm).

# Summary

- HAWC2-Matlab/Simulink is a research tool to analyzed the overall dynamics of different subsystems of wind turbines.
- Some mechanical loads on the wind turbine are qualitatively affected by emulating inertia
  1. Shaft torque,
  2. tilt moment at the tower bottom, and
  3. yaw moment at the tower top.
- Quantification of such impact on life-time would show the importance of such loading situations in the overall design of wind turbines.